

**What is Claimed is:**

1. A powder batch comprising copper metal particles, wherein said metal particles are substantially spherical, have a weight average particle size of not greater than about 5  $\mu\text{m}$  and a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size and wherein said metal particles comprise metal crystallites having an average crystallite size of at least about 40 nanometers.

2. A powder batch as recited in Claim 1, wherein said metal particles comprise at least about 50 weight percent copper metal.

3. A powder batch as recited in Claim 1, wherein said metal particles comprise at least about 80 weight percent copper metal.

4. A powder batch as recited in Claim 1, wherein at least about 95 weight percent of said metal particles are not larger than twice said average particle size.

5. A powder batch as recited in Claim 1, wherein at least about 90 weight percent of said metal particles are not larger than 1.5 times said average particle size.

6. A powder batch as recited in Claim 1, wherein at least about 95 weight percent of said metal particles are not larger than 1.5 times said average particle size.

7. A powder batch as recited in Claim 1, wherein said average crystallite size is at least about 20 percent of said average particle size.

8. A powder batch as recited in Claim 1, wherein said average crystallite size is at least about 30 percent of said average particle size.

9. A powder batch as recited in Claim 1, wherein said average crystallite size is at least about 60 nanometers.

10. A powder batch as recited in Claim 1, wherein said average crystallite size is at least about 80 nanometers.

11. A powder batch as recited in Claim 1, wherein said metal particles have a particle density of at least about 7.1 g/cm<sup>3</sup>.

12. A powder batch as recited in Claim 1, wherein said metal particles have a particle density of at least about 8.0 g/cm<sup>3</sup>.

5 13. A powder batch as recited in Claim 1, wherein said metal particles have a particle density of at least about 8.5 g/cm<sup>3</sup>.

14. A powder batch as recited in Claim 1, wherein said average particle size is from about 0.1 μm to about 3 μm.

10 15. A powder batch as recited in Claim 1, wherein said average particle size is from about 0.3 μm to about 1.5 μm.

16. A powder batch as recited in Claim 1, wherein said average particle size is from about 0.3 μm to about 0.8 μm.

17. A powder batch as recited in Claim 1, wherein not greater than about 0.5 weight percent of said metal particles are in the form of hard agglomerates.

15 18. A powder batch as recited in Claim 1, wherein said metal particles are coated particles comprising a coating substantially encapsulating an outer surface thereof.

19. A powder batch as recited in Claim 1, wherein said metal particles are composite particles comprising a non-metallic phase dispersed throughout a metal phase.

20 20. A powder batch as recited in Claim 1, wherein said powder batch has a specific surface area of not greater than about 3 m<sup>2</sup>/g.

21. A powder batch as recited in Claim 1, wherein said metal particles comprise no more than about 0.1 atomic percent impurities.

22. A powder batch as recited in Claim 1, wherein said metal particles comprise no more than about 1 weight percent copper oxide impurities.

23. A powder batch comprising copper metal particles, wherein said metal particles comprise at least about 50 weight percent copper metal wherein said metal particles are substantially spherical, have a weight average particle size of from about 0.3  $\mu\text{m}$  to about 3  $\mu\text{m}$  and a particle size distribution wherein at least about 90 weight percent of said particles are not larger than 1.5 times said average particle size and wherein said metal particles comprise metal crystallites having an average crystallite size of at least about 40 nanometers.

24. A powder batch as recited in Claim 23, wherein said metal particles have a particle density of at least about 8.5  $\text{g/cm}^3$ .

25. A powder batch as recited in Claim 23, wherein said metal particles comprise at least about 80 weight percent copper metal.

26. A powder batch as recited in Claim 23, wherein at least about 95 weight percent of said metal particles are not larger than 1.5 times said average particle size.

27. A powder batch as recited in Claim 23, wherein said average crystallite size is at least about 60 nanometers.

28. A powder batch comprising metal alloy particles, wherein said metal alloy particles comprise at least about 50 weight percent copper metal and at least a first metal alloying element, and wherein said metal alloy particles are substantially spherical, have a weight average particle size of not greater than about 5  $\mu\text{m}$ .

5 29. A powder batch as recited in Claim 28, wherein said metal alloy particles comprise crystallites having an average crystallite size of at least about 40 nanometers.

30. A powder batch as recited in Claim 28, wherein said metal alloy particles have a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size.

10 31. A powder batch as recited in Claim 28, wherein said first metal alloying element is selected from the group consisting of zinc, palladium, silver, gold, nickel, tungsten, molybdenum tin and platinum.

32. A powder batch as recited in Claim 28, wherein said first metal alloying element is zinc.

15 33. A powder batch as recited in Claim 28, wherein said first metal alloying element is homogeneously alloyed with said copper metal with substantially no phase segregation.

20 34. A powder batch as recited in Claim 28 wherein said metal alloy particles comprise from about 0.1 to about 40 weight percent of said first metal alloying element based on the total amount of metal.

35. A powder batch as recited in Claim 28 wherein said metal alloy particles comprise from about 1 to about 15 weight percent of said first metal alloying element based on the total amount of metal.

36. A powder batch as recited in Claim 28 wherein said metal alloy particles have

an average particle size of not greater than about 3  $\mu\text{m}$ .

37. A powder batch as recited in Claim 28, wherein said metal alloy particles have a lower sintering temperature than pure copper metal particles.

38. A powder batch as recited in Claim 28, wherein said metal alloy particles have  
5 a higher sintering temperature than pure copper metal particles.

39. A powder batch as recited in Claim 28, wherein said metal alloy particles have a higher vaporization temperature than pure copper metal particles.

40. A powder batch as recited in Claim 28, wherein said metal alloy particles have increased oxidation resistance compared to pure copper metal particles.

41. A powder batch comprising coated copper metal particles, said coated metal particles comprising at least about 50 weight percent copper metal and having a weight average particle size of not greater than about 5  $\mu\text{m}$  and wherein said particles comprise at least a first coating substantially encapsulating an outer surface of said particles.

5 42. A powder batch as recited in Claim 41, wherein said average particle size is not greater than about 3  $\mu\text{m}$ .

43. A powder batch as recited in Claim 41, wherein said coated metal particles have a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size.

10 44. A powder batch as recited in Claim 41, wherein said coated metal particles have a particle size distribution wherein at least about 95 weight percent of said particles are not larger than twice said average particle size.

45. A powder batch as recited in Claim 41, wherein said coated metal particles are substantially spherical.

15 46. A powder batch as recited in Claim 41, wherein said metal particles comprise crystallites having an average crystallite of at least about 40 nanometers,

47. A powder batch as recited in Claim 41, wherein said first coating has an average thickness of not greater than about 100 nanometers.

20 48. A powder batch as recited in Claim 41, wherein said first coating has an average thickness of not greater than about 50 nanometers.

49. A powder batch as recited in Claim 41, wherein said first coating comprises a metal oxide.

50. A powder batch as recited in Claim 41, wherein said first coating comprises a metal oxide selected from the group consisting of  $\text{ZrO}_2$ ,  $\text{NiO}$ ,  $\text{SiO}_2$ ,  $\text{B}_2\text{O}_5$ ,  $\text{TiO}_2$ ,  $\text{Cu}_2\text{O}$ ,  $\text{CuO}$ ,

Bi<sub>2</sub>O<sub>3</sub>, V<sub>2</sub>O<sub>5</sub> and Al<sub>2</sub>O<sub>3</sub>.

51. A powder batch as recited in Claim 41, wherein said first coating comprises a metal oxide selected from the group consisting of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>.

52. A powder batch as recited in Claim 41, wherein said first coating comprises an  
5 organic compound.

53. A powder batch as recited in Claim 41, wherein said first coating is a monolayer coating.

54. A powder batch as recited in Claim 41, wherein said first coating is a particulate coating.

55. A powder batch as recited in Claim 41, wherein said first coating is a non-  
10 particulate coating.

56. A powder batch as recited in Claim 41, wherein said first coating inhibits the sintering of said metal particles at elevated temperatures.

57. A powder batch as recited in Claim 41, wherein said first coating enhances the  
15 sintering of said metal particles.

58. A powder batch as recited in Claim 41, wherein said first coating improves the dispersibility of said metal particles in a thick film paste.

59. A powder batch as recited in Claim 41, wherein said coating increases the oxidation resistance of said metal particles.

20 60. A powder batch as recited in Claim 41, wherein said coating comprises a metal.

61. A powder batch as recited in Claim 41, wherein said coating comprises a noble metal.

62. A powder batch as recited in Claim 41, wherein said coating comprises silver metal.

63. A powder batch as recited in Claim 41, wherein said coated metal particles further comprise a second coating substantially encapsulating said first coating.



64. A powder batch comprising metal composite particles, wherein said composite particles have a weight average particle size of not greater than about 5  $\mu\text{m}$  and a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size, wherein said particles include a metal phase comprising copper metal and at least a first non-metallic phase.

65. A powder batch as recited in Claim 64, wherein said composite particles comprise at least about 50 weight percent copper metal.

66. A powder batch as recited in Claim 64, wherein said first non-metallic phase is dispersed throughout said metal phase.

67. A powder batch as recited in Claim 64, wherein said average particle size is not greater than about 3  $\mu\text{m}$ .

68. A powder batch as recited in Claim 64, wherein said average particle size is from about 0.3  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .

69. A powder batch as recited in Claim 64, wherein at least about 90 weight percent of said composite particles are not larger than 1.5 times said average particle size.

70. A powder batch as recited in Claim 64, wherein said metal phase comprises crystallites having an average crystallite size of at least about 40 nanometers.

71. A powder batch as recited in Claim 64, wherein said first non-metallic phase comprises a metal oxide.

72. A powder batch as recited in Claim 64, wherein said first non-metallic second phase comprises a metal oxide selected from the group consisting of  $\text{NiO}$ ,  $\text{SiO}_2$ ,  $\text{Cu}_2\text{O}$ ,  $\text{CuO}$ ,  $\text{B}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{V}_2\text{O}_5$  and  $\text{Al}_2\text{O}_3$ .

73. A powder batch as recited in Claim 64, wherein said first non-metallic phase is a dielectric compound selected from the group consisting of titanates, zirconates, silicates,

aluminates, tantalates and niobates.

74. A powder batch as recited in Claim 64, wherein said first non-metallic phase is a titanate.

75. A powder batch as recited in Claim 64, wherein said first non-metallic phase is selected from the group consisting of barium titanate and neodymium titanate.

76. A powder batch as recited in Claim 64, wherein said first non-metallic phase is carbon.

77. A powder batch as recited in Claim 64, wherein said composite particles comprise at least about 0.1 weight percent of said first non-metallic phase.

10 78. A powder batch as recited in Claim 64, wherein said composite particles comprise from about 0.2 to about 35 weight percent of said first non-metallic phase.

79. A powder batch as recited in Claim 64, wherein said composite particles comprise from about 0.2 to about 5 weight percent of said first non-metallic phase.

80. A powder batch comprising metal composite particles, said composite particles having a weight average particle size of not greater than about  $5\mu\text{m}$ , wherein said composite particles include a metal phase comprising copper metal and at least a first non-metallic phase comprising a ceramic dielectric compound.

5 81. A powder batch as recited in Claim 80, wherein said metal phase comprises at least about 50 weight percent copper metal.

82. A powder batch as recited in Claim 80, wherein said ceramic dielectric compound is selected from the group consisting of titanates, zirconates, silicates, aluminates, tantalates and niobates.

10 83. A powder batch as recited in Claim 80, wherein said ceramic dielectric compound is a titanate.

84. A powder batch as recited in Claim 80, wherein said ceramic dielectric compound is selected from the group consisting of barium titanate and neodymium titanate.

15 85. A powder batch as recited in Claim 80, wherein said weight average particle size is from about  $0.3\mu\text{m}$  to about  $1.5\mu\text{m}$ .

86. A powder batch as recited in Claim 80, wherein said composite particles have a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size.

20 87. A powder batch as recited in Claim 80, wherein said first non-metallic phase is homogeneously dispersed throughout said metal phase.

88. A powder batch as recited in Claim 80, wherein said composite particles comprise at least about 0.1 weight percent of said first non-metallic phase.

89. A powder batch as recited in Claim 80, wherein said composite particles comprise from about 0.2 to about 35 weight percent of said first non-metallic phase.

90. A powder batch as recited in Claim 80, wherein said composite particles comprise from about 0.2 to about 5 weight percent of said first non-metallic phase.

91. A multilayer ceramic capacitor comprising internal electrodes fabricated from a metal composite powder as recited in Claim 80 .

92. A thick-film paste composition suitable for screen printing onto a substrate, comprising:

- a) a binder phase;
- b) an organic vehicle phase; and

5 c) a functional phase, said functional phase comprising copper metal particles, wherein said copper metal particles are substantially spherical, have a weight average particle size of not greater than about 5  $\mu\text{m}$  and an average crystallite size of at least about 40 nanometers.

10 93. A paste composition as recited in Claim 92, wherein said copper metal particles have a particle size distribution wherein at least about 90 weight percent of said metal particles are not larger than twice said average particle size.

94. A paste composition as recited in Claim 92, wherein said copper metal particles have a particle size distribution wherein at least about 95 weight percent of said metal particles are not larger than twice said average particle size.

15 95. A paste composition as recited in Claim 92, wherein said average particle size is not greater than about 3  $\mu\text{m}$ .

96. A paste composition as recited in Claim 92, wherein said average particle size is from about 0.3  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .

20 97. A paste composition as recited in Claim 92, wherein said copper metal powder is a metal alloy particle comprising an effective amount of an alloying element to increase the oxidation resistance of the copper metal powder.

98. A paste composition as recited in Claim 92, wherein said binder phase comprises a glass frit.

99. A paste composition as recited in Claim 92, wherein said organic vehicle phase

comprises a high molecular weight polymer dissolved in a solvent.

100. A paste composition as recited in Claim 92, wherein said organic vehicle phase comprises a polymer dissolved in a solvent, wherein said polymer is selected from the group consisting of ethyl cellulose, polyvinyl acetate, cellulose resin and acrylic resin and said  
5 solvent is selected from the group consisting of methanol, ethanol, terpineol, butyl carbitol, butyl carbitol acetate, aliphatic alcohols, esters and acetone.

101. A paste composition as recited in Claim 92, wherein said paste composition comprises from about 5 to about 95 weight percent of said functional phase.

102. A paste composition as recited in Claim 92, wherein said paste composition  
10 comprises from about 60 to about 85 weight percent of said copper metal particles.

103. A paste composition as recited in Claim 92, wherein said copper metal particles are composite particles comprising copper metal and a non-metallic phase.

104. A paste composition as recited in Claim 92, wherein said copper metal particles are composite particles comprising copper metal and a non-metallic second phase dispersed  
15 throughout said copper metal.

105. A paste composition as recited in Claim 92, wherein said copper metal particles are coated metal particles comprising a coating substantially encapsulating said particles.

106. A paste composition as recited in Claim 92, wherein said copper metal particles are coated metal particles comprising a metal oxide coating substantially encapsulating an  
20 outer surface thereof.

107. A thick-film paste composition suitable for screen printing onto a substrate, comprising:

- a) a binder phase;
- b) an organic vehicle phase; and

5           c) a functional phase, said functional phase comprising composite copper metal particles having a weight average particle size not greater than about 5  $\mu\text{m}$ , said composite particles including a metal phase comprising copper metal and at least a first non-metallic phase.

108. A paste composition as recited in Claim 107, wherein said composite metal  
10 particles have a particle size distribution wherein at least about 90 weight percent of said particles are not larger than twice said average particle size.

109. A paste composition as recited in Claim 107, wherein said composite particles comprise at least about 50 weight percent copper metal.

110. A paste composition as recited in Claim 107, wherein said first non-metallic  
15 phase comprises a metal oxide.

111. A paste composition as recited in Claim 107, wherein said first non-metallic phase is dispersed throughout said copper metal phase.

112. A paste composition as recited in Claim 107, wherein said first non-metallic phase is a ceramic dielectric compound.

20           113. A paste composition as recited in Claim 107, wherein said first non-metallic phase is a ceramic dielectric compound selected from the group consisting of titanates, zirconates, silicates, aluminates, tantalates and niobates.

114. A paste composition as recited in Claim 107, wherein said first non-metallic phase is a ceramic dielectric compound comprising a titanate.

115. A paste composition as recited in Claim 107, wherein said composite particles comprise from about 0.2 to about 5 weight percent of said first non-metallic phase.

116. A paste composition as recited in Claim 107, wherein said composite copper metal particles comprise up to about 75 weight percent copper metal and wherein said first  
5 non-metallic phase is a metal oxide selected from the group consisting of alumina and silica.

117. A paste composition as recited in Claim 107, wherein said metal phase comprises crystallites having an average crystallite size of at least about 40 nanometers.

118. A paste composition as recited in Claim 107, wherein said weight average particle size is from about 0.3  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .



119. A green body suitable for sintering to form a multilayer ceramic capacitor, comprising:

a) a plurality of stacked green sheets comprising a dielectric ceramic material; and

5 b) a thick film paste composition disposed between said sheets, wherein said thick film paste composition comprises a binder phase, an organic vehicle phase and a functional phase and wherein said functional phase comprises copper metal particles having a substantially spherical shape and having a weight average particle size of not greater than about 5  $\mu\text{m}$  and an average crystallite size of at least about 40 nanometers.

10 120. A green body as recited in Claim 119, wherein said copper metal particles have a particle size distribution wherein at least about 90 weight percent of said copper metal particles are not larger than twice said average particle size.

121. A green body as recited in Claim 119, wherein said average particle size is from about 0.3  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .

15 122. A green body as recited in Claim 119, wherein said average particle size is from about 0.3  $\mu\text{m}$  to about 0.8  $\mu\text{m}$ .

123. A green body as recited in Claim 119, wherein said copper metal particles are composite particles comprising a copper metal phase and a non-metallic phase.

20 124. A green body as recited in Claim 119, wherein said copper metal particles are composite particles comprising copper metal and a metal oxide dispersed throughout said copper metal.

125. A green body as recited in Claim 119, wherein said copper metal particles are composite particles comprising copper metal and a dielectric compound selected from the group consisting of titanates, zirconates, silicates, aluminates, tantalates and niobates.

126. A green body as recited in Claim 119, wherein said copper metal particles are composite particles comprising copper metal and a dielectric compound comprising a titanate.

127. A green body as recited in Claim 119, wherein said copper metal particles are  
5 coated particles comprising a coating substantially encapsulating said particles.

128. A green body as recited in Claim 119, wherein said copper metal particles are coated particles comprising a metal oxide coating substantially encapsulating said particles.

129. A green body as recited in Claim 119, wherein said copper metal particles are coated particles comprising a noble metal coating.

10 130. A green body as recited in Claim 119, wherein said copper metal particles are coated particles comprising a silver metal coating.

131. A multilayer ceramic capacitor formed from a green body as recited in Claim  
119.

132. An intermediate component for a microelectronic device, wherein said component comprises an insulative substrate and a thick film paste disposed on said substrate, said thick film paste comprising copper metal particles having a weight average particle size of not greater than about 5  $\mu\text{m}$  and a particle size distribution wherein at least about 90  
5 weight percent of said particles are not larger than twice said average particle size and wherein said copper metal particles comprise crystallites having an average crystallite size of at least about 40 nanometers.

133. An intermediate component as recited in Claim 132, wherein said substrate comprises a ceramic.

10 134. An intermediate component as recited in Claim 132, wherein said substrate is a green ceramic sheet.

135. An intermediate component as recited in Claim 132, wherein said substrate is a sintered ceramic.

136. An intermediate component as recited in Claim 132, wherein said weight  
15 average particle size is from about 0.3  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .

137. An intermediate component as recited in Claim 132, wherein said thick film paste is adapted to form a plurality of conductive traces disposed in substantially parallel relation and having an average pitch of not greater than about 25  $\mu\text{m}$ .

138. An intermediate component as recited in Claim 132, wherein said  
20 microelectronic device is a multichip module.

139. A multilayer ceramic capacitor, comprising:

- a) a plurality of ceramic dielectric layers;
- b) a plurality of internal electrode layers disposed between said dielectric

layers; and

- 5 c) external electrodes connected to said internal electrodes, wherein said external electrodes are formed from copper metal particles having a weight average particle size of from about 1  $\mu\text{m}$  to about 3  $\mu\text{m}$  and an average crystallite size of at least about 40 nanometers.

140. A multilayer capacitor as recited in Claim 139, wherein said copper metal  
10 particles are composite metal particles comprising copper metal and a metal oxide phase.

141. A multilayer ceramic capacitor as recited in Claim 139, wherein said internal electrode layers comprise nickel metal.

142. A method for the production of copper metal particles, comprising the steps of:  
a) generating an aerosol of droplets from a liquid wherein said liquid comprises a copper metal precursor and wherein said droplets have a size distribution such that at least about 80 weight percent of said droplets have a size of from about 1  $\mu\text{m}$  to about

5 5  $\mu\text{m}$ ;

b) moving said droplets in a carrier gas; and  
c) heating said droplets to remove liquid therefrom and form copper metal particles comprising at least about 50 weight percent copper metal.

143. A method as recited in Claim 142, wherein said carrier gas comprises hydrogen.

10 144. A method as recited in Claim 142, wherein said carrier gas comprises hydrogen and an inert gas.

145. A method as recited in Claim 142, wherein said carrier gas comprises at least about 10 moles hydrogen gas for every mole of copper.

15 146. A method as recited in Claim 142, wherein said heating step comprises carrying said droplets through a heating zone having a reaction temperature of not greater than about 1400° C.

147. A method as recited in Claim 142, wherein said heating step comprises carrying said droplets through a heating zone having a reaction temperature of from about 900° C to about 1300°

20 148. A method as recited in Claim 142, wherein said heating step comprises carrying said droplets through a heating zone having a reaction temperature of from about 1150°C to about 1300°C.

149. A method as recited in Claim 142, wherein said heating step comprises carrying said droplets through a heating zone having a reaction temperature of from about

1000° C to about 1350° C and wherein said carrier gas comprises at least about 10 moles hydrogen gas for every mole of copper.

150. A method as recited in Claim 142, wherein said metal particles have a particle density of at least about 8.0 g/cc.

5 151. A method as recited in Claim 142, wherein said metal particles have a particle density of at least about 8.5 g/cc.

10 152. A method as recited in Claim 142, wherein said step of generating an aerosol comprises the step of removing a first portion of droplets from said aerosol, wherein said removed droplets have an aerodynamic diameter greater than a preselected maximum

153. A method as recited in Claim 142, wherein said droplets have a size distribution such that not more than about 20 weight percent of the droplets in said aerosol are larger than about twice the weight average droplet size.

15 154. A method as recited in Claim 142, further comprising the step of concentrating said aerosol by removing a second portion of said droplets from said aerosol, wherein said second portion of droplets have an aerodynamic diameter less than a preselected minimum diameter.

20 155. A method as recited in Claim 142, wherein said liquid is a solution comprising a copper metal precursor selected from the group consisting of copper nitrate, copper hydroxide, copper chloride, copper sulfate and copper oxalate.

156. A method as recited in Claim 142, wherein said liquid is a solution comprising copper nitrate.

157. A method as recited in Claim 142, wherein said liquid is a solution comprising from about 1 to about 15 weight percent copper.

158. A method as recited in Claim 142, wherein said liquid comprises a copper metal precursor and a reducing agent.

159. A method as recited in Claim 142, wherein said liquid comprises copper nitrate and hydrazine.

5 160. A method as recited in Claim 142, wherein said liquid further comprises a densification aid.

161. A method as recited in Claim 142, wherein said liquid further comprises urea.

162. A method as recited in Claim 142, wherein said liquid further comprises a precursor to at least one metal alloying element.

10 163. A method as recited in Claim 142, further comprising the step of coating an outer surface of said copper metal particles.

164. A method as recited in Claim 142, wherein said copper metal particles are metal composite particles comprising a non-metallic phase dispersed throughout said particles.

165. A method as recited in Claim 142, further comprising the step of quenching said copper metal particles in a gas stream comprising air.

166. A method for the production of metal composite particles, comprising the steps of:

- a) forming a liquid solution comprising a copper metal precursor and a non-metallic phase precursor;
- b) generating an aerosol of droplets from said liquid solution;
- c) moving said droplets in a carrier gas;
- d) heating said droplets to remove liquid therefrom and form metal composite particles comprising copper metal and a non-metallic phase.

167. A method as recited in Claim 166, wherein said carrier gas comprises hydrogen.

168. A method as recited in Claim 166, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of not greater than about 1400° C.

169. A method as recited in Claim 166, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of from about 950° C to about 1200° C.

170. A method as recited in Claim 166, wherein said metal composite particles have a particle density of at least about 90 percent of the theoretical density for said metal composite particles.

171. A method as recited in Claim 166, wherein said aerosol droplets have an average size of from about 1  $\mu\text{m}$  to about 5  $\mu\text{m}$  and wherein not more than about 20 weight percent of said droplets are larger than about twice said average droplet size.

172. A method as recited in Claim 166, wherein said step of generating an aerosol comprises the step of removing a first portion of droplets from said aerosol wherein said droplets in said first portion have an aerodynamic diameter greater than a preselected



maximum diameter.

173. A method as recited in Claim 166, further comprising the step of concentrating said aerosol and removing a second portion of said droplets from said aerosol, wherein said droplets in said second portion have an aerodynamic diameter less than a preselected minimum diameter.

174. A method as recited in Claim 166, wherein said copper metal precursor is selected from the group consisting of copper nitrate, copper hydroxide, copper chloride, copper sulfate and copper oxalate.

175. A method as recited in Claim 166, wherein said copper metal precursor is copper nitrate.

176. A method as recited in Claim 166, wherein said liquid comprises copper nitrate and a reducing agent.

177. A method as recited in Claim 166, wherein said non-metallic phase precursor comprises a metal salt dissolved in said liquid solution.

178. A method as recited in Claim 166, wherein said non-metallic phase precursor comprises particles suspended in said liquid solution.

179. A method as recited in Claim 166, wherein said non-metallic phase is a metal oxide.

180. A method as recited in Claim 166, wherein said non-metallic phase is a metal oxide selected from the group consisting of silica and alumina.

181. A method as recited in Claim 166, wherein said non-metallic phase is a ceramic dielectric compound.

182. A method as recited in Claim 166, wherein said metal composite particles comprise copper metal and not greater than about 25 weight percent of said non-metallic

phase.

183. A method as recited in Claim 166, further comprising the step of coating an outer surface of said metal composite particles.

184. A method for the production of metal alloy particles, comprising the steps of:

- a) forming a liquid solution comprising a copper metal precursor and a second metal precursor;
- b) generating an aerosol of droplets from said liquid solution;
- c) moving said droplets in a carrier gas;
- d) heating said droplets to remove liquid therefrom and form metal alloy particles comprising copper metal and a second metal.

185. A method as recited in Claim 184, wherein said carrier gas comprises hydrogen.

186. A method as recited in Claim 184, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of not greater than about 1400° C.

187. A method as recited in Claim 184, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of from about 950° C to about 1200° C.

188. A method as recited in Claim 184, wherein said metal alloy particles have a particle density of at least about 90 percent of the theoretical density for said metal alloy particles.

189. A method as recited in Claim 184, wherein said aerosol droplets have an average droplet size of from about 1  $\mu\text{m}$  to about 5  $\mu\text{m}$  and wherein not more than about 20 weight percent of said droplets have a size greater than about twice said average droplet size.

190. A method as recited in Claim 184, wherein said step of generating an aerosol comprises the step of removing a first portion of droplets from said aerosol wherein said droplets in said removed first portion have an aerodynamic diameter greater than a preselected maximum diameter.

191. A method as recited in Claim 184, further comprising the step of concentrating said aerosol and removing a second portion of said droplets from said aerosol, wherein said droplets in said removed second portion have an aerodynamic diameter less than a preselected minimum diameter.

192. A method as recited in Claim 184, wherein said copper metal precursor is selected from the group consisting of copper nitrate, copper hydroxide, copper chloride, copper sulfate and copper oxalate.

193. A method as recited in Claim 184, wherein said copper metal precursor is copper nitrate.

194. A method as recited in Claim 184, wherein said liquid comprises copper nitrate and a reducing agent.

195. A method as recited in Claim 184, wherein said non-metallic phase precursor comprises a metal salt dissolved in said liquid solution.

196. A method as recited in Claim 184, wherein said non-metallic phase precursor comprises particles suspended in said liquid solution.

197. A method as recited in Claim 184, wherein said second metal is selected from the group consisting of palladium, gold, tungsten, molybdenum, platinum, tin and zinc.

198. A method as recited in Claim 184, wherein said second metal is zinc.

199. A method as recited in Claim 184, wherein said metal alloy particles comprise copper metal and from about 0.1 to 40 weight percent of said second metal phase.

200. A method as recited in Claim 184, wherein said metal alloy particles are homogeneously alloyed with substantially no phase segregation of said copper metal and said second metal.

201. A method as recited in Claim 184, further comprising the step of coating an

outer surface of said metal alloy particles.

202. A method for the production of coated copper metal particles, comprising the steps of:

- a) forming a liquid solution comprising a copper metal precursor;
- b) generating an aerosol of droplets from said liquid solution;
- c) moving said droplets in a carrier gas;
- d) heating said droplets to remove liquid therefrom and form metal particles

comprising copper metal; and

- e) coating an outer surface of said copper metal particles.

203. A method as recited in Claim 202, wherein said coating step comprises contacting said metal particles with a volatile coating precursor.

204. A method as recited in Claim 202, wherein said coating step comprises contacting said metal particles with a volatile coating precursor selected from the group consisting of metal chlorides, metal acetates and metal alkoxides.

205. A method as recited in Claim 202, wherein said coating step comprises contacting said metal particles with silicon tetrachloride to form a silica coating on said particles.

206. A method as recited in Claim 202, wherein said carrier gas comprises hydrogen.

207. A method as recited in Claim 202, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of not greater than about 1400° C.

208. A method as recited in Claim 202, wherein said heating step comprises passing said droplets through a heating zone having a reaction temperature of from about 950° C to about 1200° C.

209. A method as recited in Claim 202, wherein said coated particles have a particle

density of at least about 90 percent of the theoretical density for said metal particles.

210. A method as recited in Claim 202, wherein said aerosol droplets have an average size of from about 1  $\mu\text{m}$  to about 5  $\mu\text{m}$  and wherein not greater than about 20 weight percent of said droplets are larger than about twice said average droplet size.

211. A method as recited in Claim 202, further comprising the step of concentrating said aerosol and removing a first portion of droplets from said aerosol wherein said droplets in said removed first portion have an aerodynamic diameter greater than a preselected maximum diameter.

212. A method as recited in Claim 202, further comprising the step of removing a second portion of said droplets from said aerosol, wherein said droplets in said removed second portion have an aerodynamic diameter less than a preselected minimum diameter.

213. A method as recited in Claim 202, wherein said copper metal precursor is selected from the group consisting of copper nitrate, copper hydroxide, copper chloride, copper sulfate and copper oxalate.

214. A method as recited in Claim 202, wherein said copper metal precursor is copper nitrate.

215. A method as recited in Claim 202, wherein said liquid comprises a copper metal precursor comprising copper nitrate and a reducing agent comprising hydrazine.

216. A method as recited in Claim 202, wherein said coating is a metal oxide.

217. A method as recited in Claim 202, wherein said coating is a metal oxide selected from the group consisting of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{ZrO}_2$ ,  $\text{B}_2\text{O}_5$ ,  $\text{TiO}_2$ ,  $\text{Cu}_2\text{O}$ ,  $\text{CuO}$ ,  $\text{ZnO}$ ,  $\text{V}_2\text{O}_5$  and  $\text{Bi}_2\text{O}_3$ .

218. A method as recited in Claim 202, wherein said coating comprises a noble metal.

219. A method as recited in Claim 202, wherein said coating is silver metal.

220. A method as recited in Claim 202, wherein said coating has an average thickness of not greater than about 100 nanometers.

221. A method as recited in Claim 202, wherein said coating has an average thickness of not greater than about 50 nanometers.